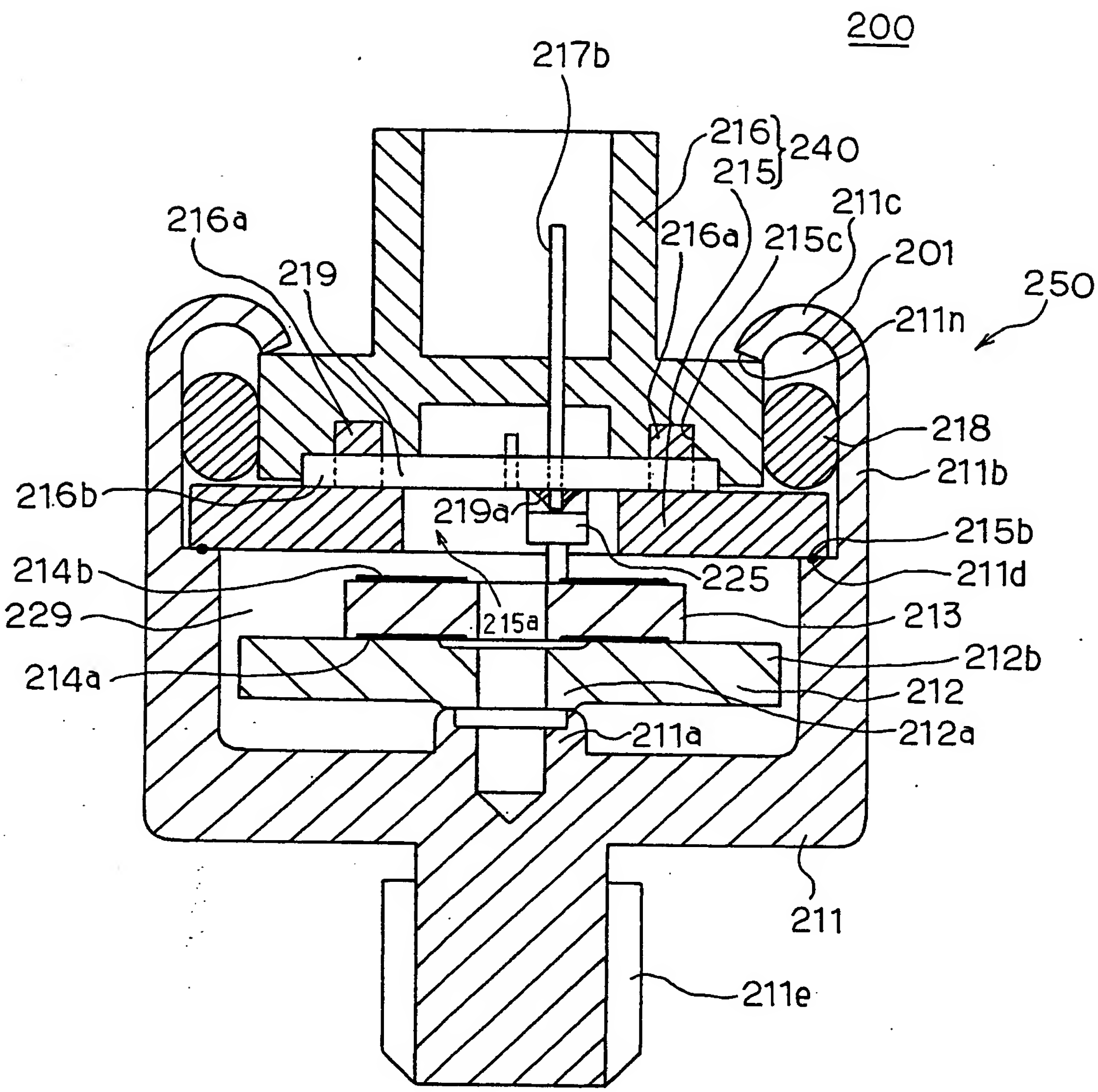
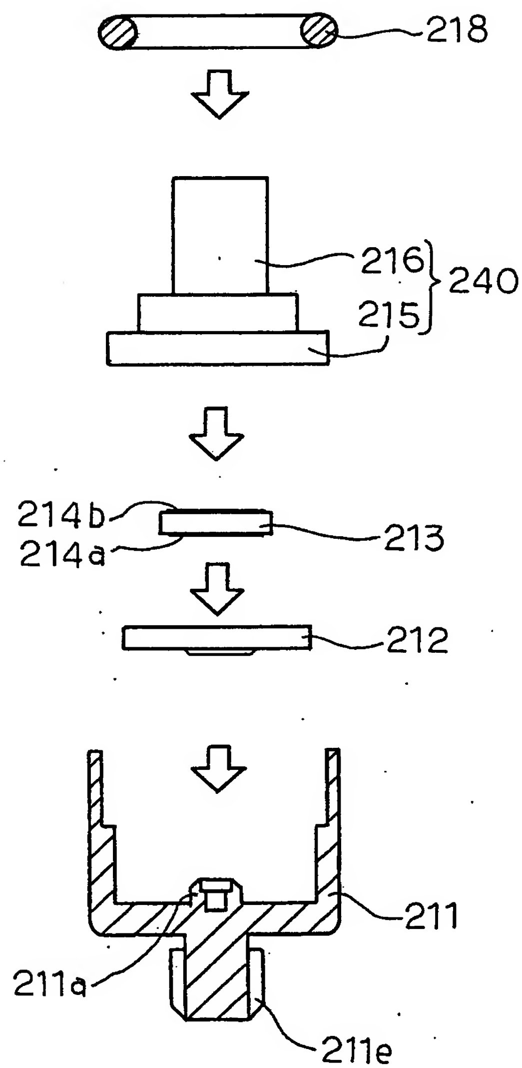
F I G. 1



200
217b
216
215
240
211c
216a
219
216a
215c
201
250
211n
218
211b
216b
219a
215b
214b
225
211d
229
215a
213
212b
214a
212
211a
212a
211
211e

F I G. 2



F I G. 3

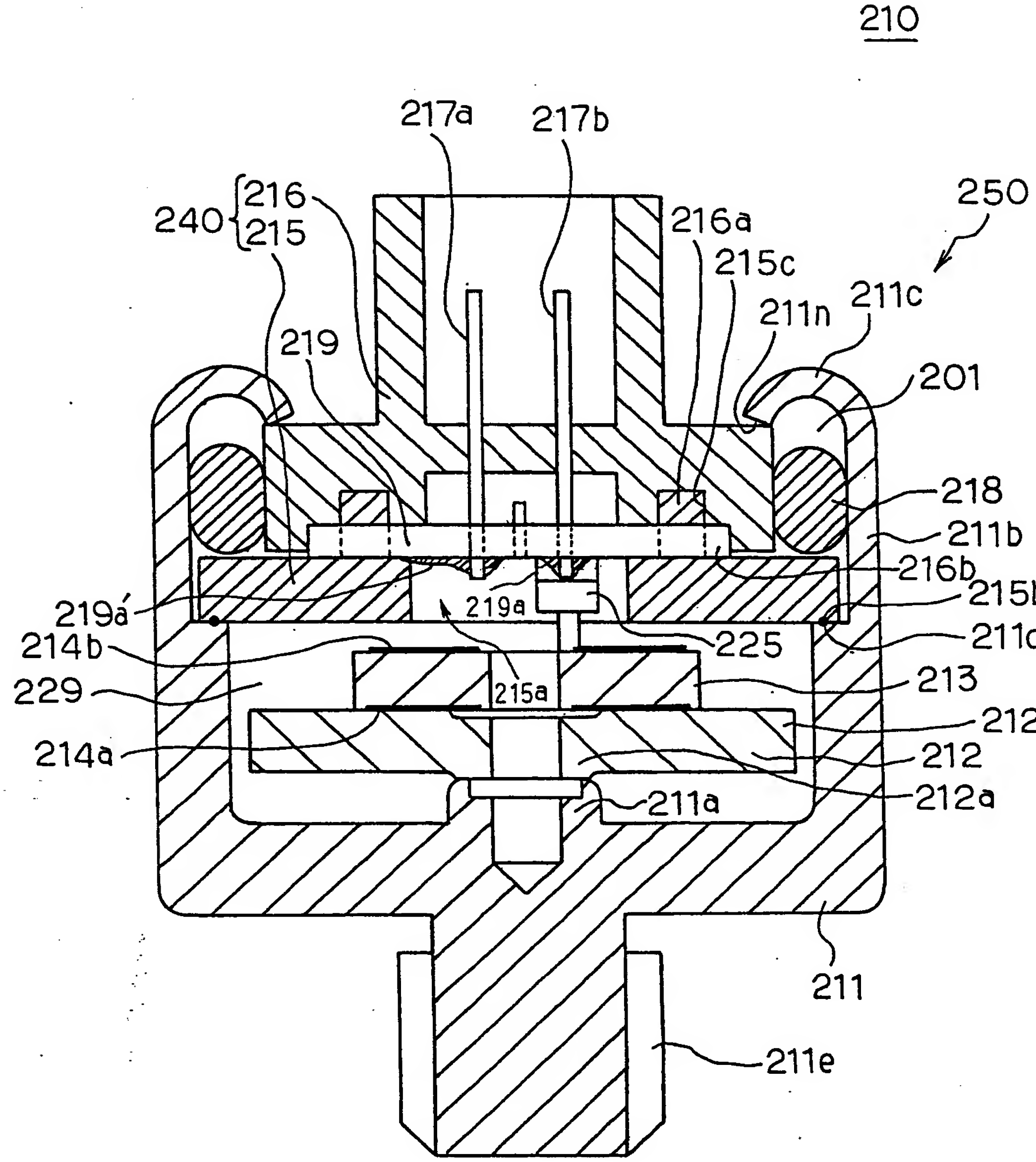
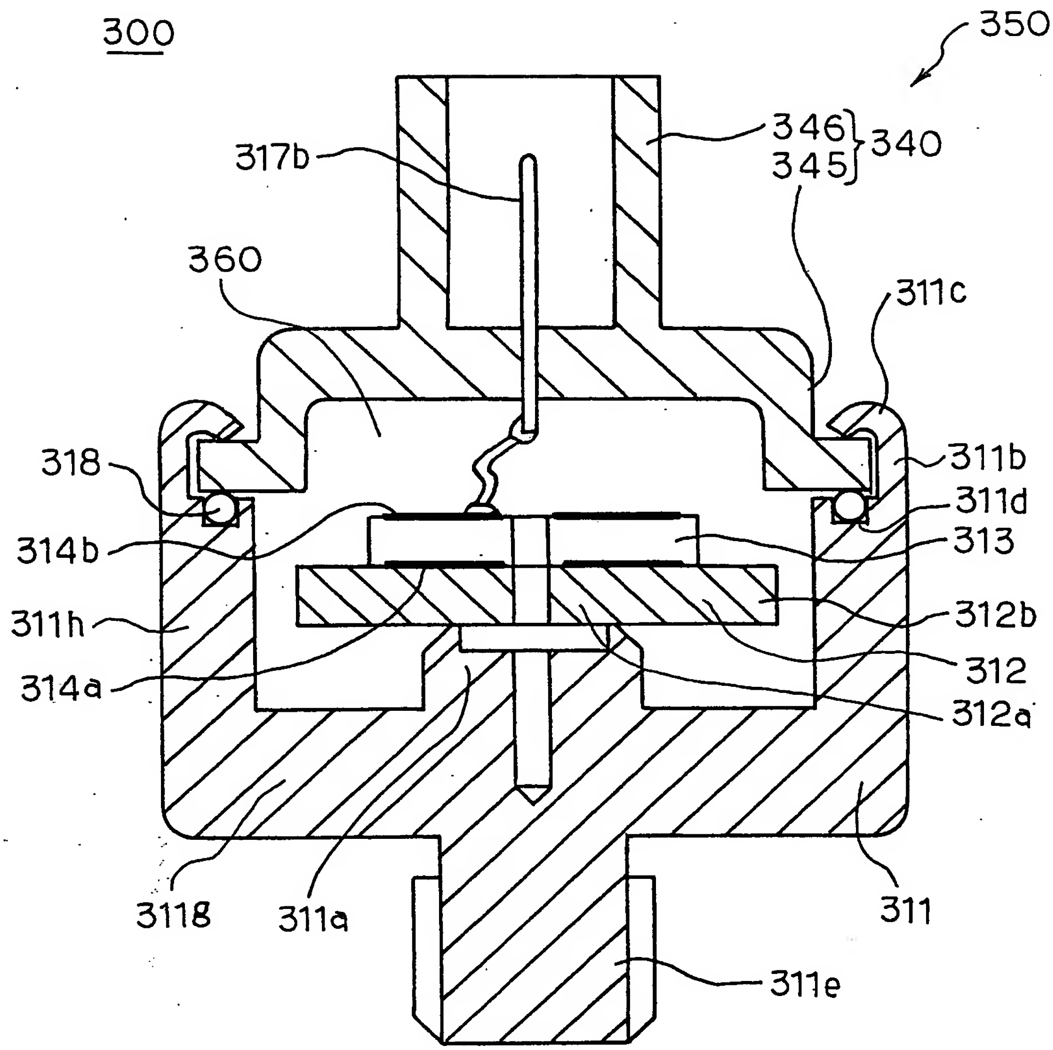
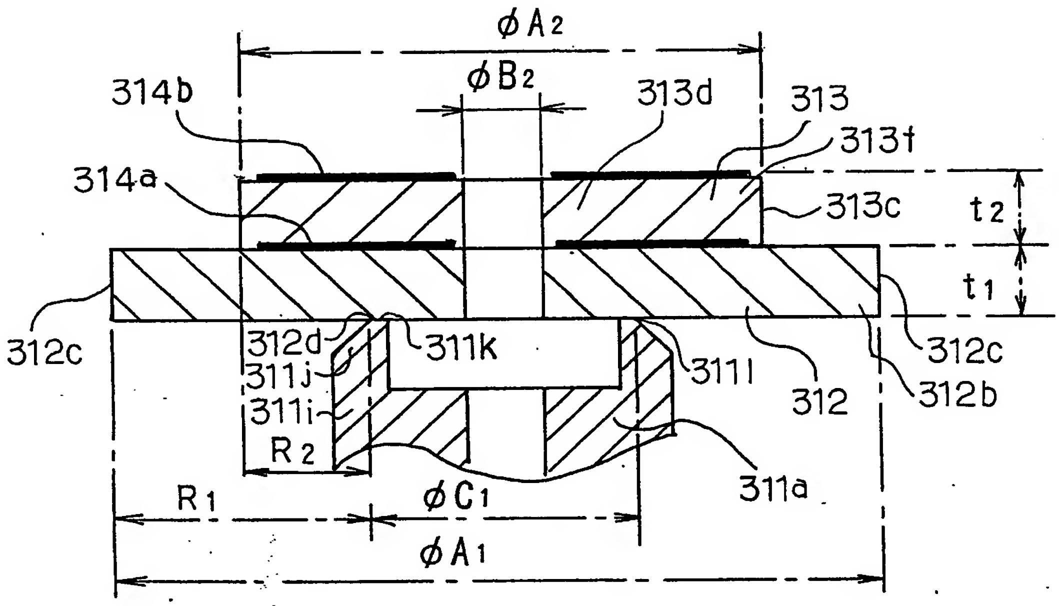

210
217a
217b
240
216
215
216a
215c
250
211n
211c
219
201
218
211b
216b
219a'
219a
215b
211d
214b
225
229
215a
213
212b
214a
212
212a
211a
211
211e

FIG. 4



300
350
346
345
340
317b
360
311c
318
311b
311d
314b
313
311h
312b
312
314a
312a
311g
311a
311
311e

F I G. 5

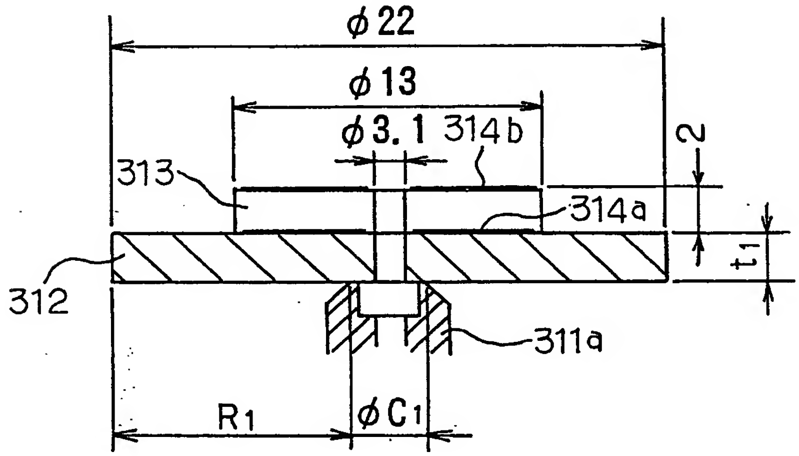


φA2
φB2
314b
313d
313
313f
314a
313c
t2
t1
312c
312d
311k
311l
312c
311j
312
312b
311i
R2
311a
R1
φC1
φA1

FIG. 6

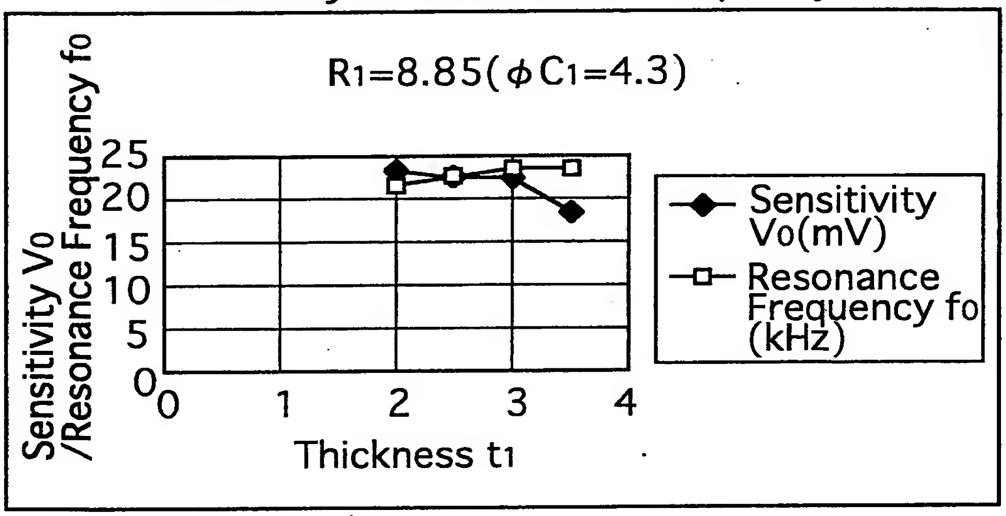
Constants / Material	E : Young's modules (N/m^2)	ρ :Density (kg/m^3)	σ : Poisson's ratio
Oscillation Plate (Nickel Steel)	2×10^{11}	7.8×10^{3}	0.28
Piezoelectric Element(PZT)	6.3×10^{10}	7.65×10^{3}	0.34

FIG. 7



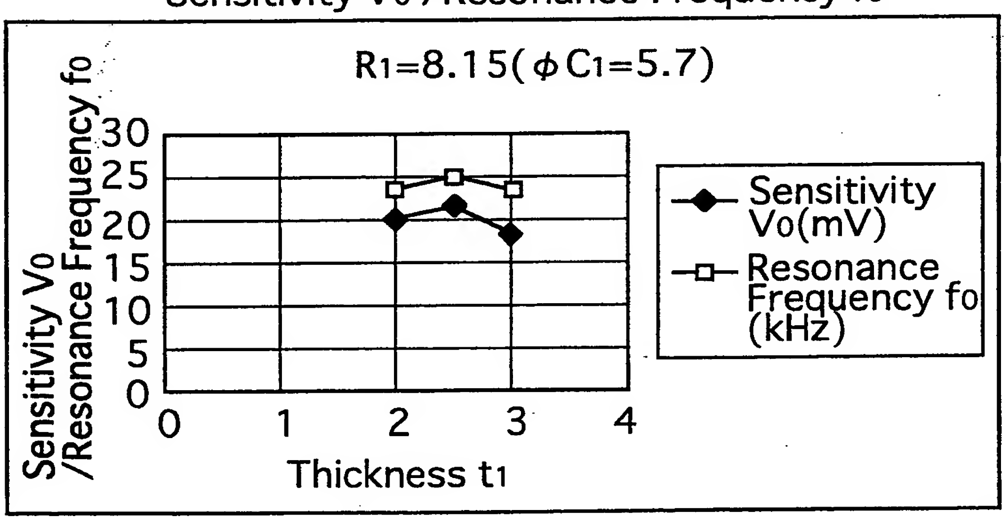
F I G. 8 A

Relationship between Thickness t_1 and Sensitivity V_0 /Resonance Frequency f_0

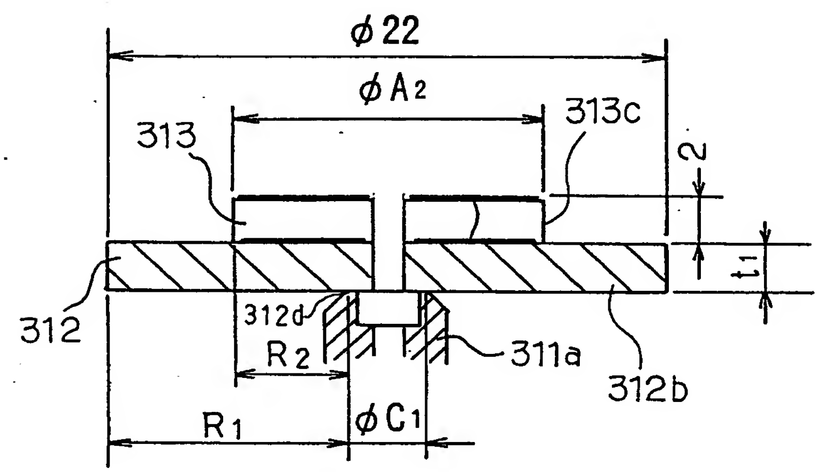


F I G. 8 B

Relationship between Thickness t_1 and Sensitivity V_0 /Resonance Frequency f_0

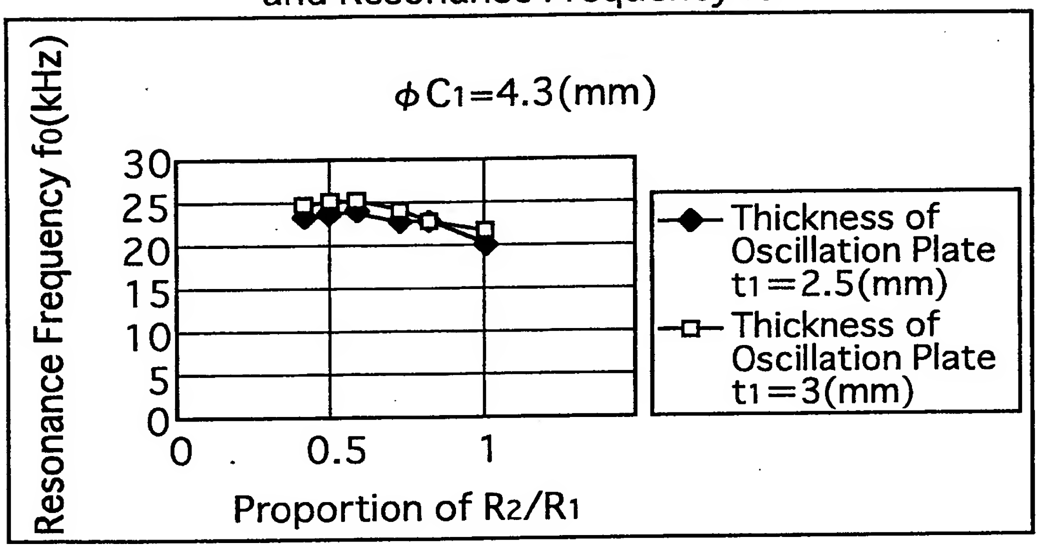


F I G. 9



F I G. 1 0 A

Relationship between Proportion of R2/R1 and Resonance Frequency fo



F I G. 1 0 B

Relationship between Proportion of R2/R1 and Resonance Frequency fo

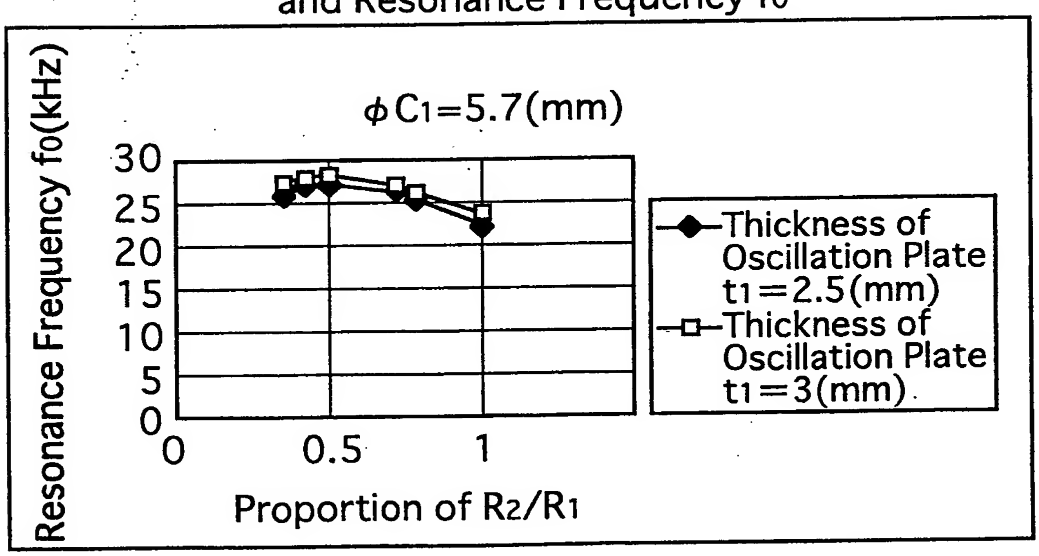
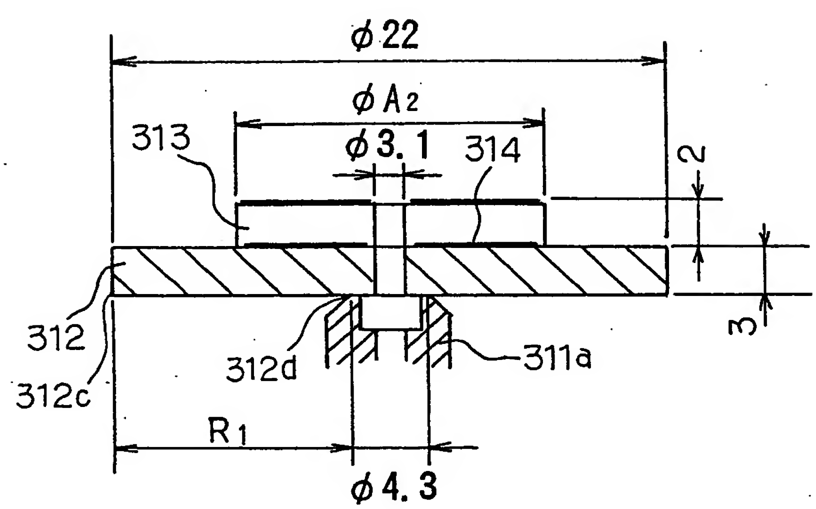


FIG. 11



F I G. 1 2

Relationship between Proportion of R_2/R_1
and Sensitivity V_0(mV)/
Resonance Frequency f_0 (kHz)

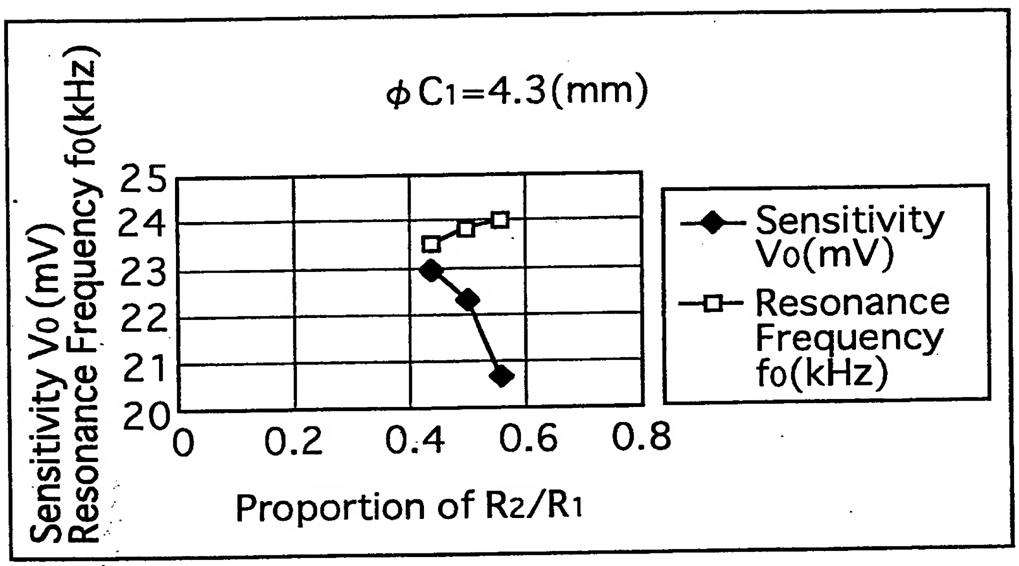


FIG. 13

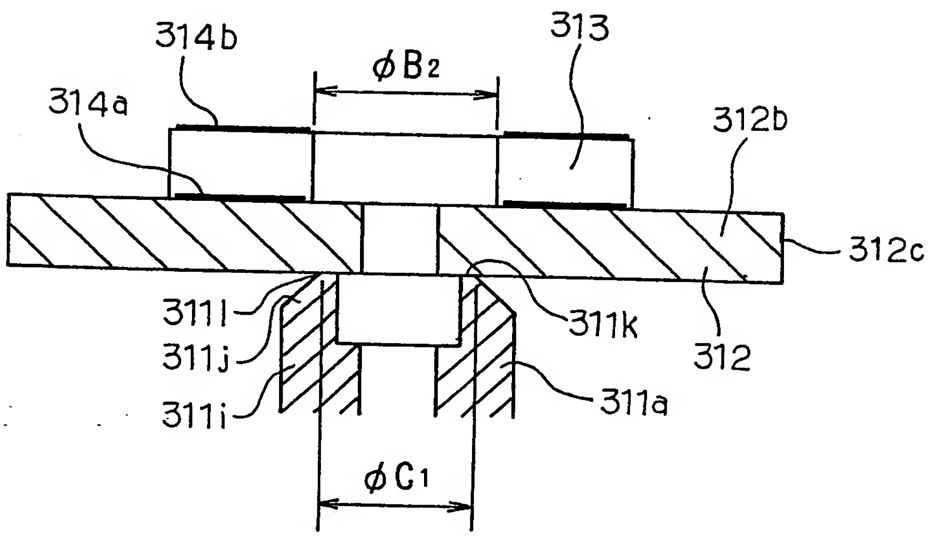

314b
ϕB_2
313
314a
312b
312c
311l
311k
311j
312
311i
311a
ϕC_1

FIG. 14

Relationship between Sensitivity V_0 /Resonance Frequency f_0, Inner Diameter of Piezoelectric Element, i.e.,B_2(mm) with respect to Diameter of Supporting Portion, i.e.,C_1(mm)

$\phi A_2/\phi B_2$ \ ϕC_1		$\phi 13/\phi 4.9$ $t_2=2$		$\phi 13/\phi 3.1$ $t_2=2$	
		2	3	2	3
$\phi 4.3$	V_0	26.1	23.7	22.8	22.4
	f_0	21.0	23.5	21.5	23.8
$\phi 5.7$	V_0	22.1	18.0	19.9	18.2
	f_0	23.0	25.3	23.3	23.3

Outer Diameter of Oscillation Body $\phi A_1=22$(mm) V_0:(mV) f_0:(kHz)

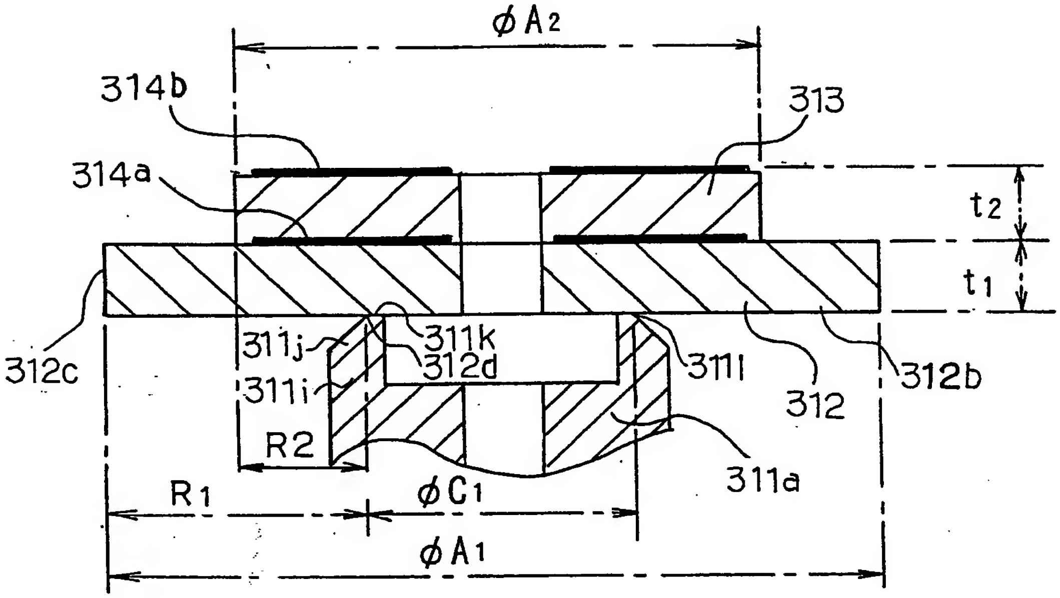
FIG. 15

Relationship between Sensitivity V_0 /Resonance Frequency f_0, and Proportion of Thickness of Oscillation Plate t_1 with respect to Thickness of Piezoelectric Element t_2

<table>
<tr><td colspan="3">t_1/t_2
ϕC_1</td><td>0.67</td><td>1</td><td>1.25</td><td>1.5</td><td>2</td><td>3</td></tr>
<tr><td rowspan="4">ϕ4.3</td><td rowspan="2">$t_1=2$</td><td>Vo</td><td>20.7</td><td>22.8</td><td>22.5</td><td rowspan="2"></td><td>22.7</td><td rowspan="2"></td></tr>
<tr><td>fo</td><td>21.8</td><td>21.5</td><td>21.0</td><td>19.0</td></tr>
<tr><td rowspan="2">$t_1=3$</td><td>Vo</td><td rowspan="2"></td><td>21.9</td><td rowspan="2"></td><td>22.4</td><td rowspan="2"></td><td>19.8</td></tr>
<tr><td>fo</td><td>24.3</td><td>23.8</td><td>22.5</td></tr>
</table>

Outer Diameter of Piezoelectric Element $\phi A_2=13$(mm) Vo:(mV) fo:(kHz)

F I G. 1 6



φA2
314b
313
314a
t2
t1
312c
311j
311k
312d
311i
311l
312
312b
R2
311a
R1
φC1
φA1

FIG. 17

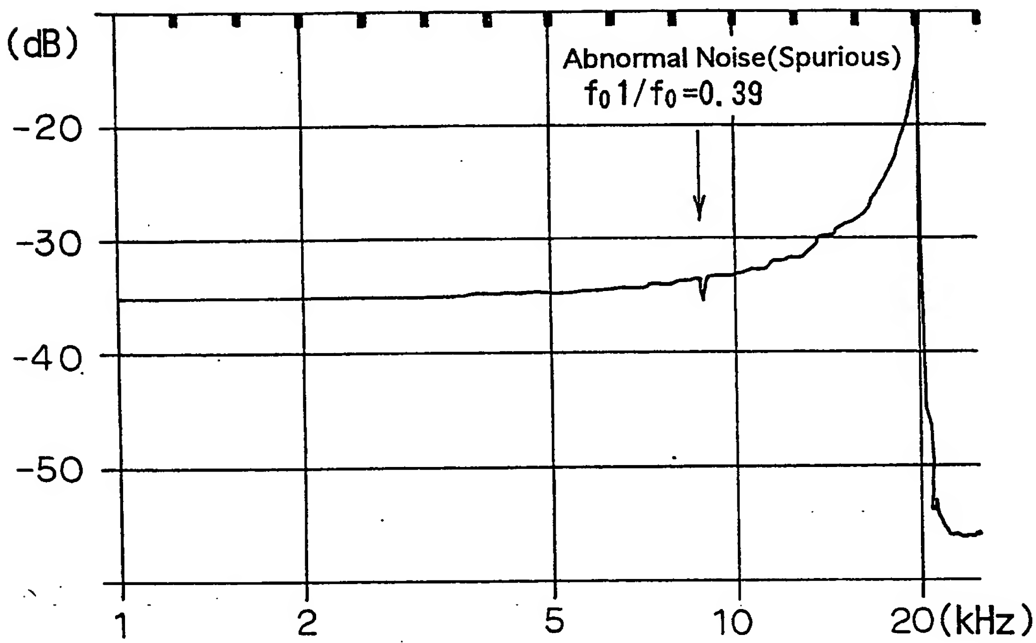
Result of Experiments

φA1	φC1	φC1/R1 \ φA2	φ12	φ13	φ14	φ15	φ16
φ20	φ4.2	0.55	× 0.39				
	φ5.7	0.80	× 0.47	× 0.46	× 0.37		
	φ6.3	0.92	○ ≧0.57	○ ≧0.55	× 0.46		
	φ7.3	1.15		○ ≧0.53	○ ≧0.53	○ ≧0.53	
φ22	φ7.3	0.99			× 0.51	× 0.49	
	φ8.7	1.31			○ ≧0.53	○ ≧0.52	○ ≧0.52

- t1=t2=2(mm)
- ○(Pass) : Spurious was not recognized
- ×(Fail) : Spurious was recognized
- ○/×(Pass/fail) was judged at an upper limit frequency of the range of effective frequencies, i.e., 15(kHz).
- Values stated below ○ or × : $f_0 1/f_0$

FIG. 18

Result of Experiments



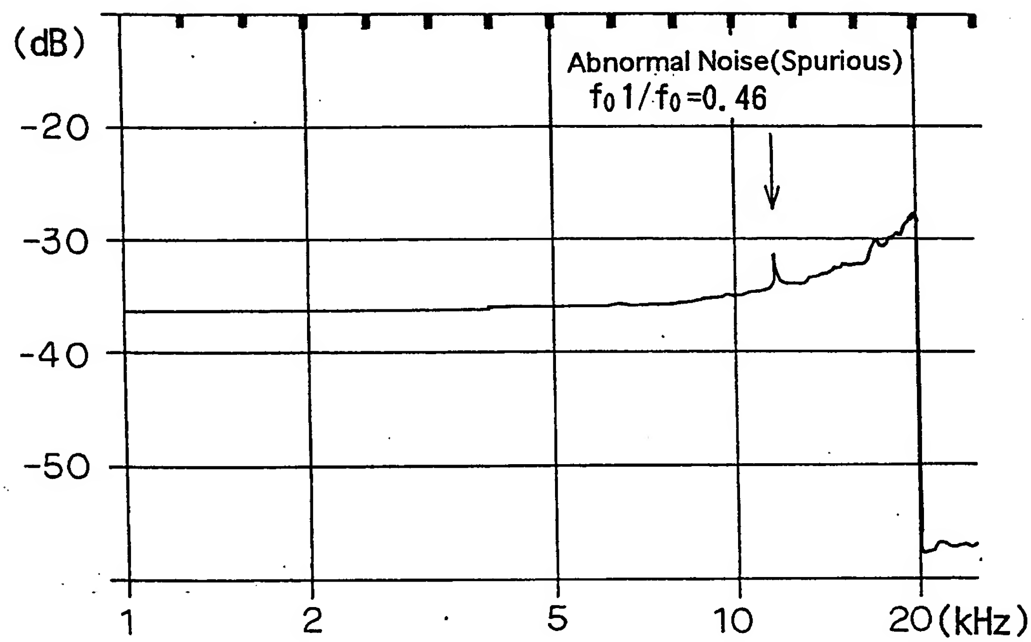
ϕC_1=4.2

$\phi C_1/R_1$=0.55

f_0=23(kHz)

F I G. 1 9

Result of Experiments



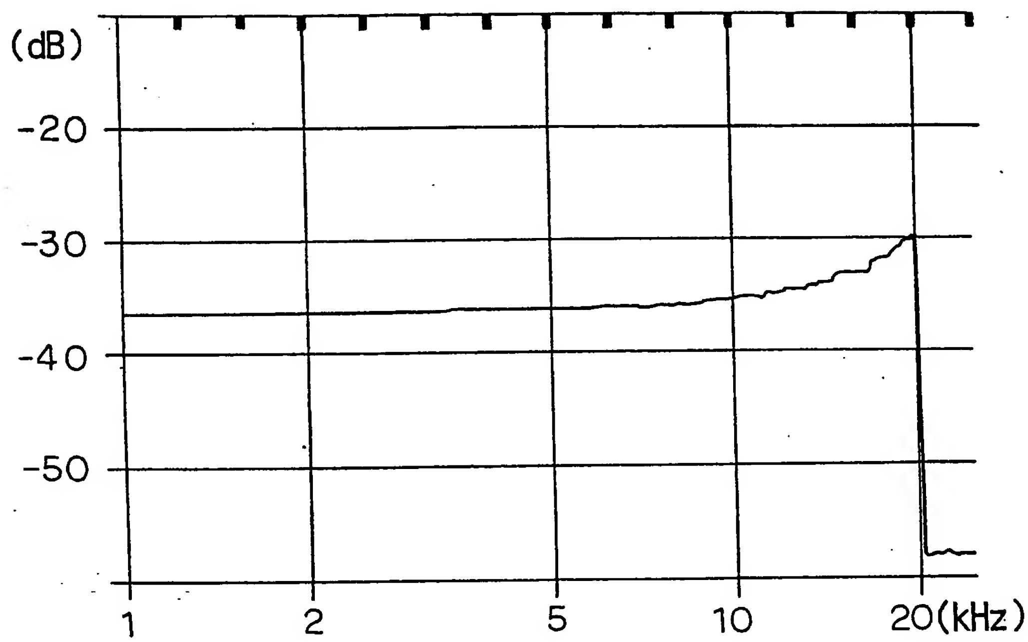
$\phi C_1=5.7$

$\phi C_1/R_1=0.80$

$f_0=26.3$ (kHz)

FIG. 20

Result of Experiments



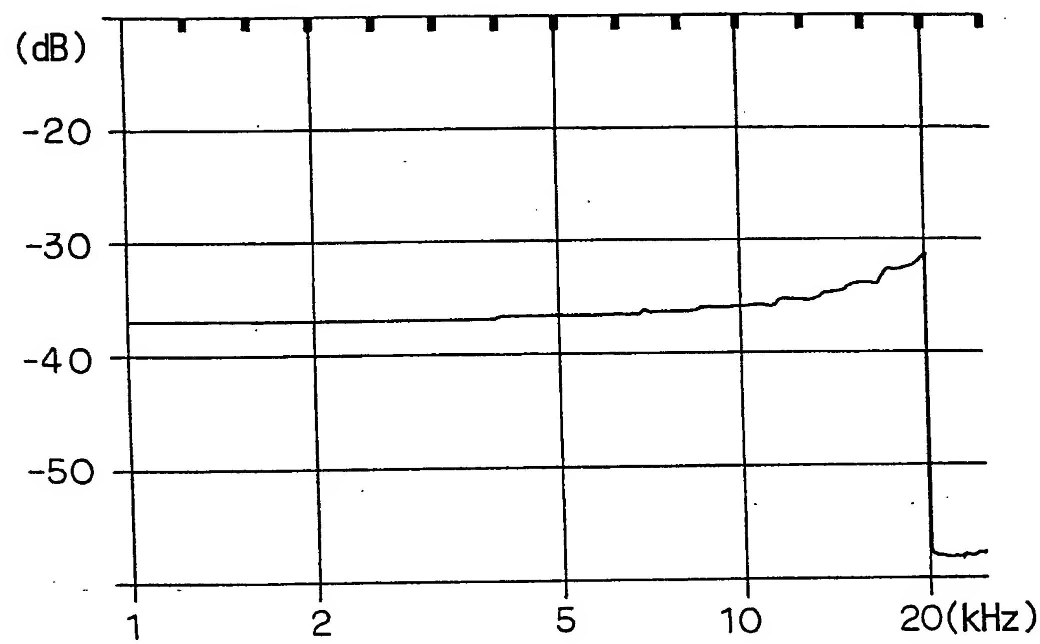
$\phi C_1 = 6.3$

$\phi C_1 / R_1 = 0.92$

$f_0 = 27.3$ (kHz)

F I G. 2 1

Result of Experiments

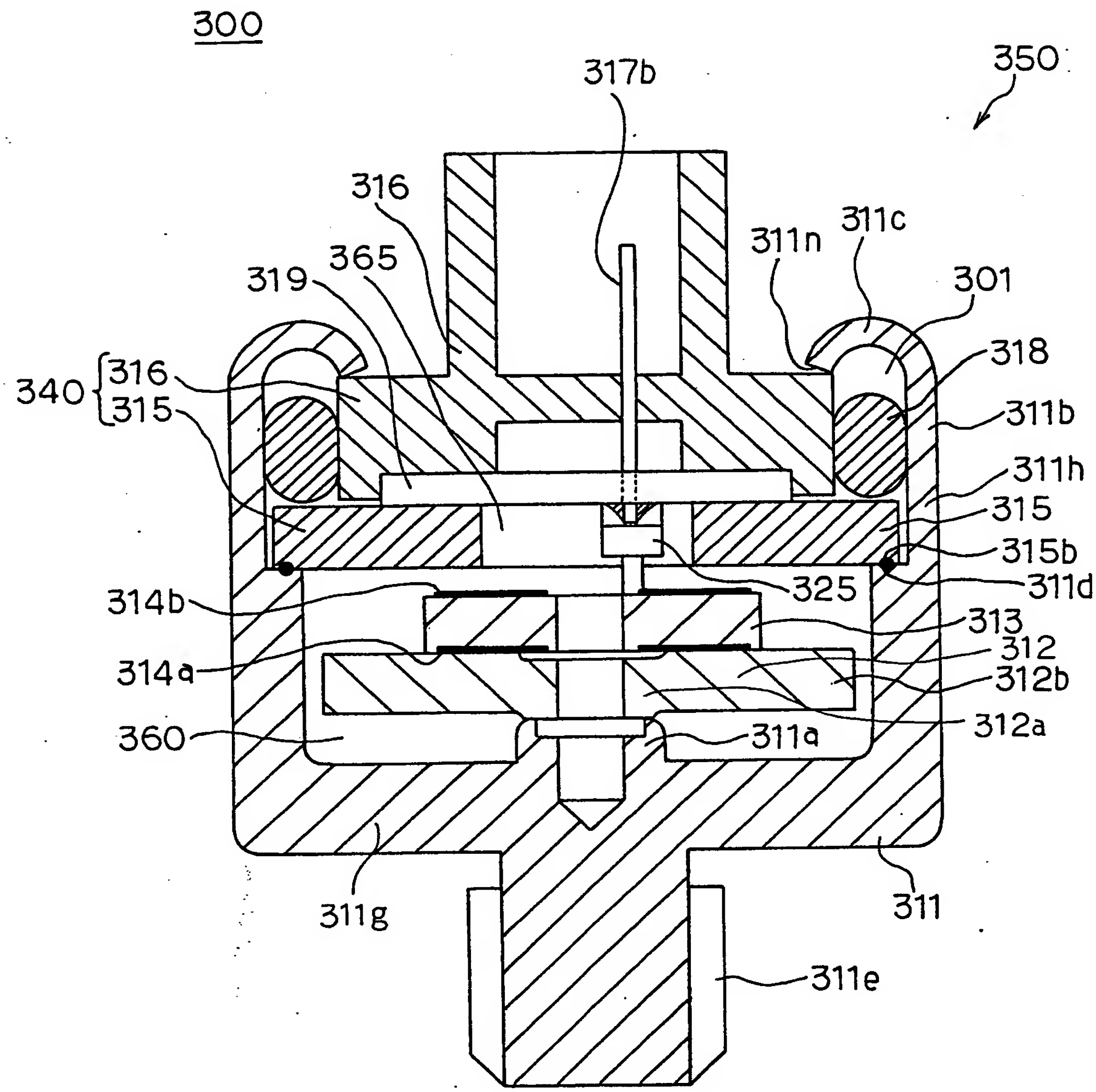


$\phi C_1 = 7.3$

$\phi C_1 / R_1 = 1.15$

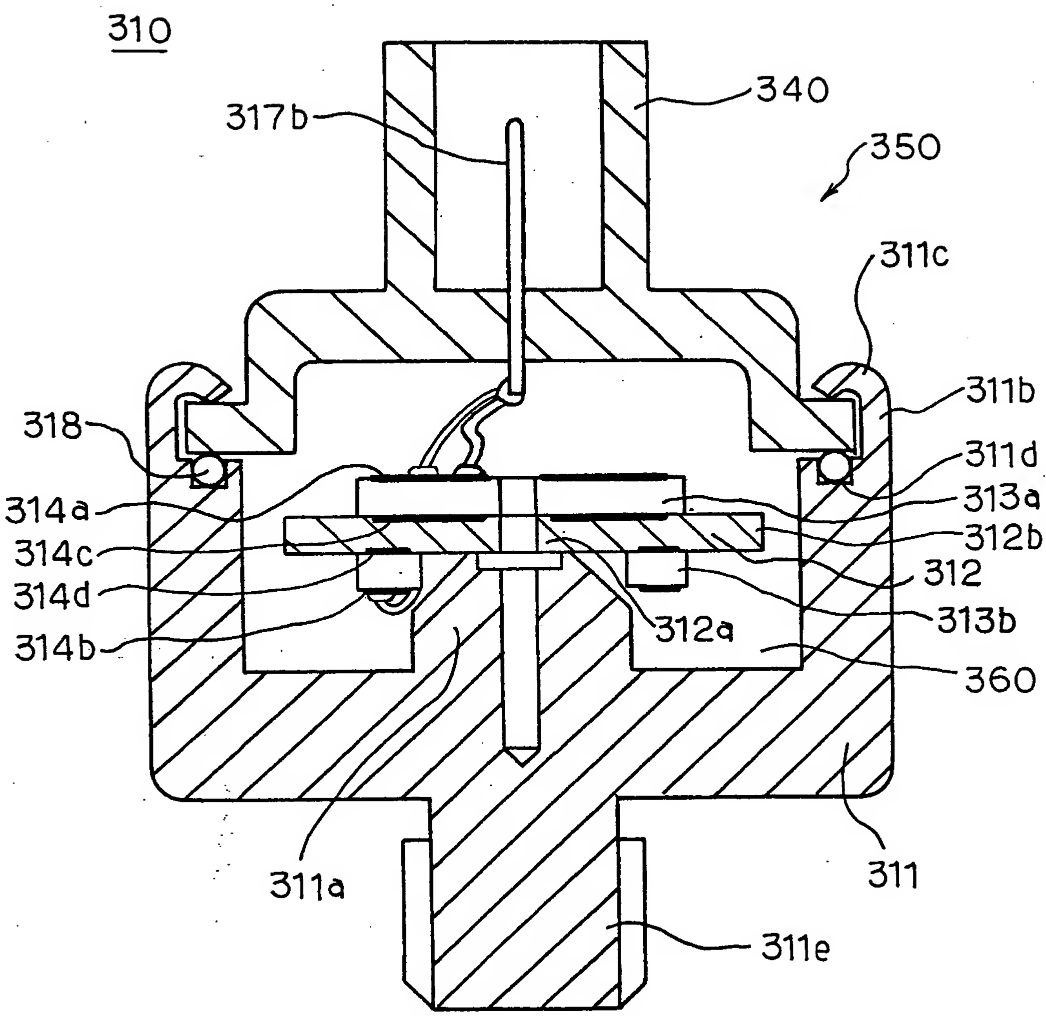
$f_0 = 30.3$(kHz)

F I G. 2 2



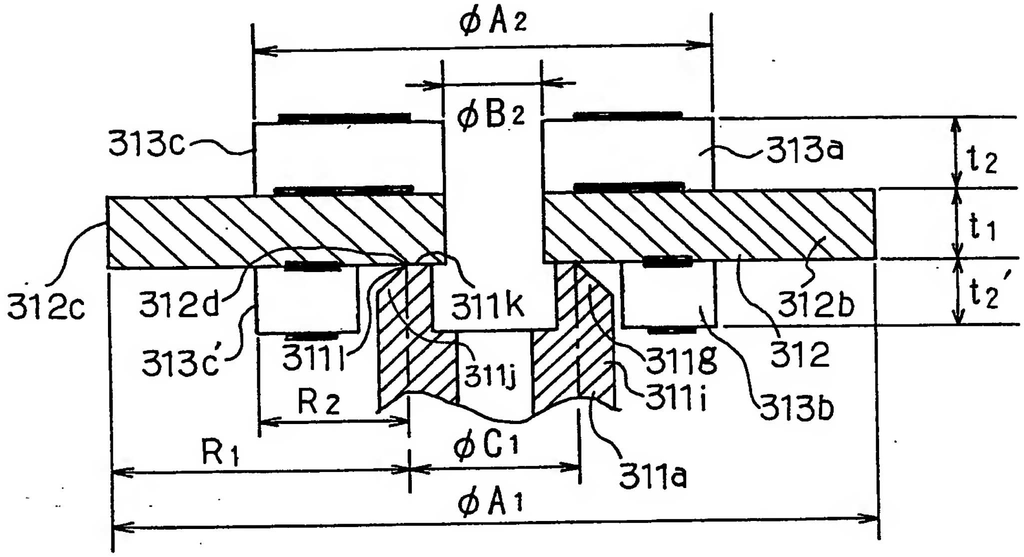
300
350
317b
316
365
319
311n
311c
301
318
340
316
315
311b
311h
315
315b
311d
325
314b
313
312
314a
312b
312a
360
311a
311g
311
311e

F I G. 2 3



310
317b
340
350
311c
311b
318
311d
314a
313a
314c
312b
314d
312
312a
313b
314b
360
311a
311
311e

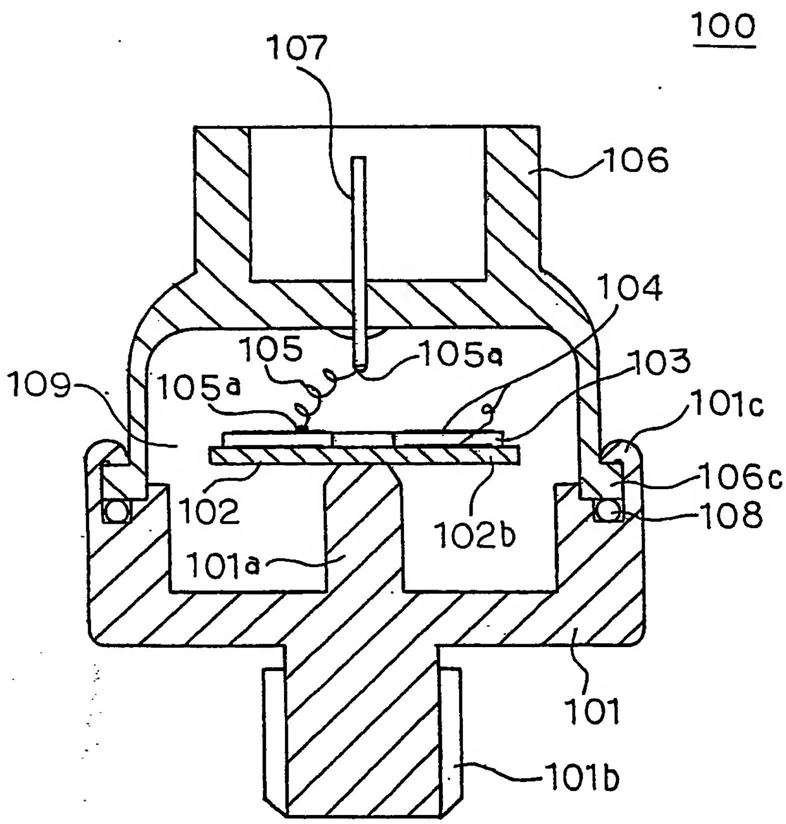
F I G. 2 4



ϕA2
ϕB2
313c
313a
t2
t1
t2'
312c
312d
311k
312b
313c'
311l
311j
311g
312
311i
313b
R2
R1
ϕC1
311a
ϕA1

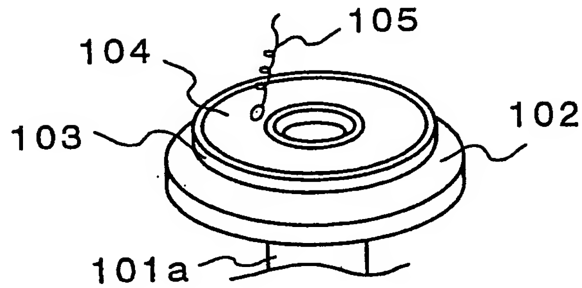
F I G. 25

PRIOR ART



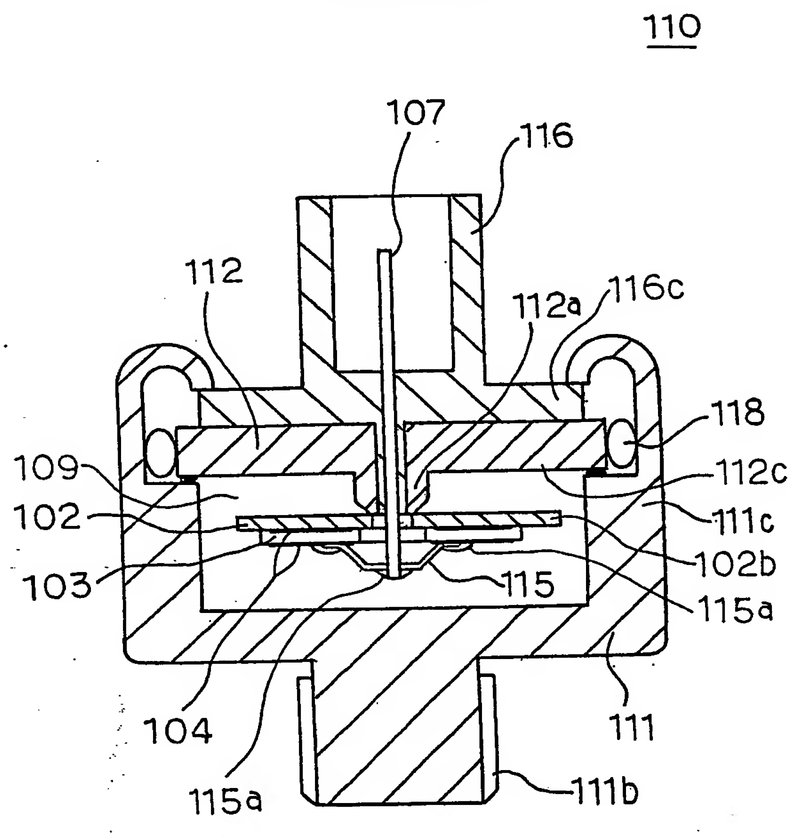
F I G. 2 6

PRIOR ART



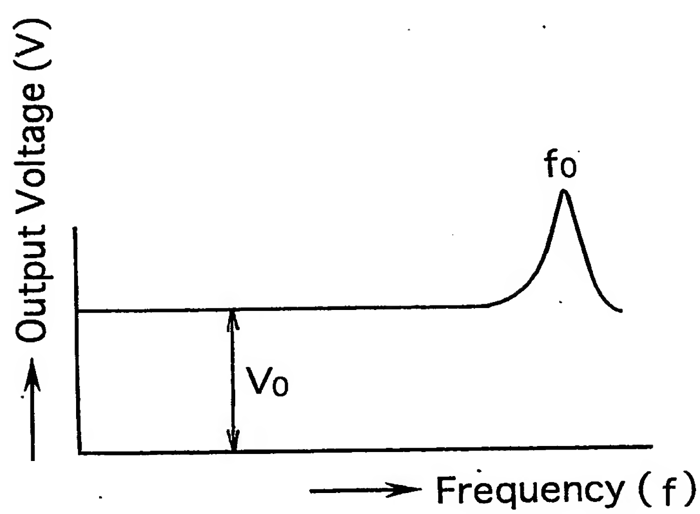
F I G. 2 7

PRIOR ART



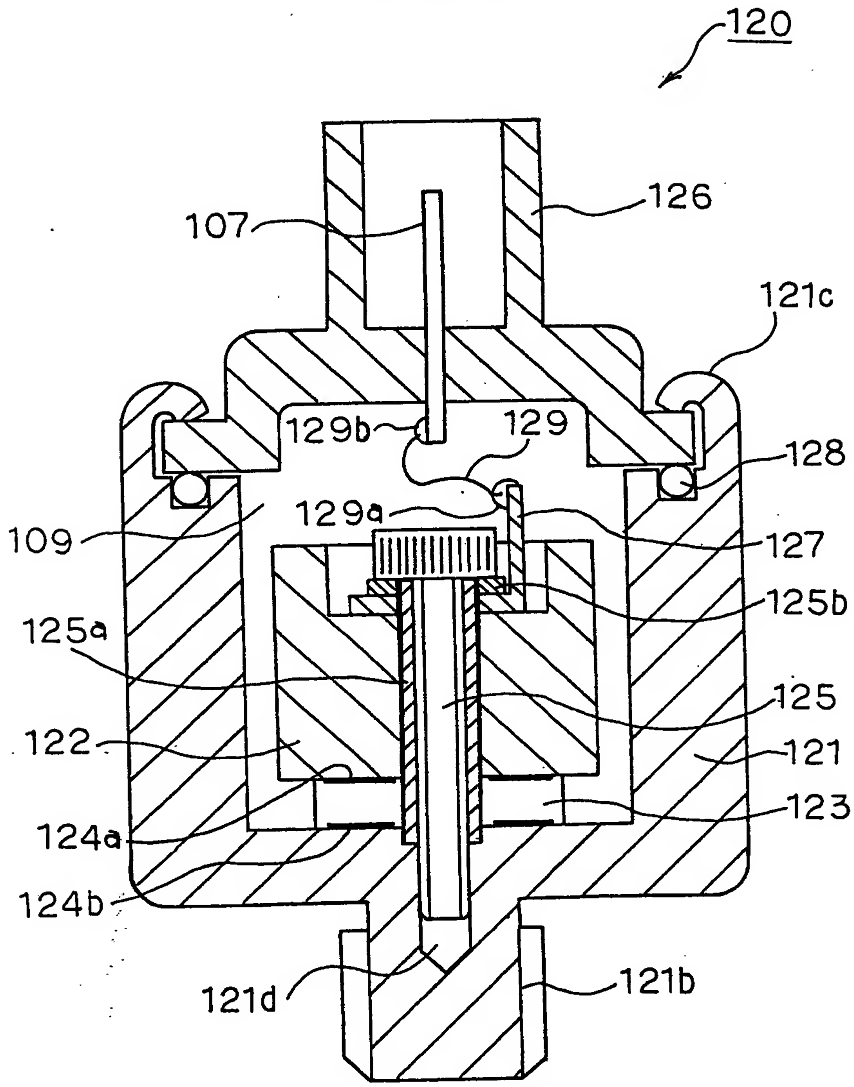
F I G. 2 8

Relationship between frequency f and output voltage V



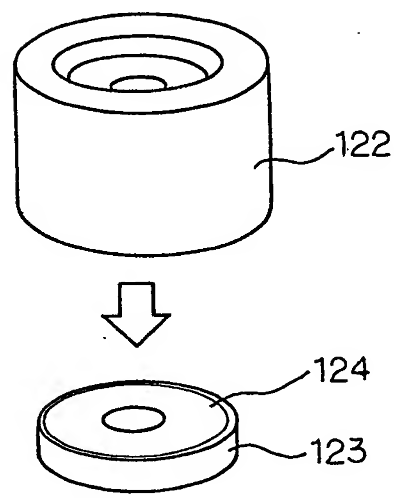
F I G. 2 9

PRIOR ART



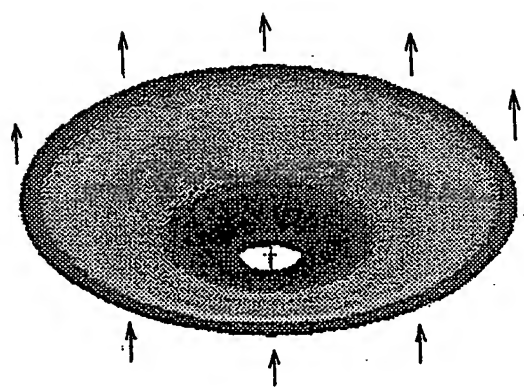
F I G. 3 0

PRIOR ART



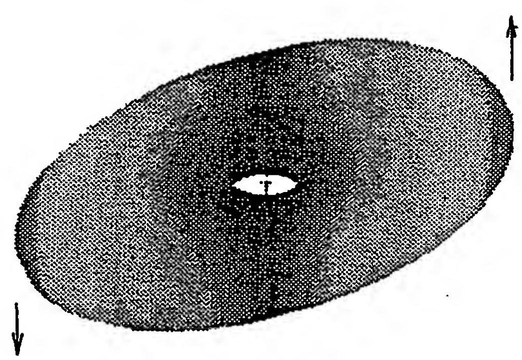
F I G. 31A

1/1 Oscillation Mode



F I G. 31B

1/2 Oscillation Mode



F I G. 31C

1/4 Oscillation Mode